The Effects of Certain Growth Inhibitors on Sprouting of Tubers and Character of Growth of the Dahlia

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THE EFFECTS OF CERTAIN GROWTH INHIBITORS ON SPROUTING OF TUBERS AND CHARACTER OF GROWTH OF THE DAHLIA

by

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INTRODUCTION

Premature sprouting of dahlia tubers in storage is quite common as is true with many other cultivated tubers. Most tubers may be held for short periods without detrimental effects, but after long periods of storage (6 to 8 mo.), excessive sprouting and shriveling are likely to occur.

Zimmerman and Hitchcock (49), and Allen (2) studied storage of dahlia tubers. They found that dahlia tubers keep best at temperatures between 35° and 50° F, and relative humidities between 80 and 85 percent.

The best known practice is to provide optimum temperature and humidity conditions for holding the crop, as indicated by the above research. This is what is actually done by the commercial grower in most cases, but for the home gardener proper storage conditions are usually not available.

The advance in knowledge of growth regulators in recent years seemed to offer a promising line of attack. A review of the literature revealed that the problem had been, in part, solved for storage of many edible roots and tubers. The results of the treatment on the subsequent crop if treated stock were used as seed, were in most cases not considered. It was evident that only temporary inhibition is needed for that part of the crop which is to be planted the following season.

The objective of this experiment was to obtain information which may be used to formulate a more convenient and economical method of storage that will reduce excessive sprouting and shriveling until tubers are ready to plant.

This study was designed to find the best chemical and the correct concentration of it to satisfy the objective stated above. Complete inhibition is not wanted as it interferes with the germination and growth of the tubers after they are planted.

REVIEW OF LITERATURE

A. The physiology of growth in relation to growth regulators

Growth of plants, according to Boysen Jensen (7), is a result of the many physical and chemical reactions within the plant. The substances involved in these processes may be classified as either nutritional or regulating. The nutritional group furnishes energy and material for building the plant. They are mainly water, minerals and gases; all of which are required in relatively large quantities. The second group, the regulating substances, are of greater importance to this paper. They are the chemical activators, spoken of in a broad sense as hormones.

Hormones, according to Boysen Jensen (7), were first associated with animal physiology by Starling in 1906. In 1910 Hans Fitting applied the word to a water extract of orchid pollen. When the extract was applied to an orchid flower it caused the petals to fall and the ovary to swell.

However, according to Boysen Jensen (7), Charles Darwin is most often associated with the early concepts of growth regulators. His classic experiment with grass proved that the tips, or something within the tips, was responsible for bending toward light. When the tips of the coleoptiles were covered with tin foil or cut off, no bending occurred.

Between 1914 and 1919, according to Boysen Jensen (7), A. Paal discovered that when the tip of an oat coleoptile was cut off and placed to one side, the coleoptile was induced to grow on that side and bend from the tip. His explanation was that the curvature was due to an unequal distribution of a growth-regulating substance.

His conclusion is still good today. Tukey (44) states that P. Boysen Jensen had already demonstrated that the stimulus from the tips would diffuse through a thin section of gelatin and cause a curvature, but that F. W. Went of Utrecht, Holland carried the experiment a step further. In 1926 Dr. Went placed tips of oat coleoptiles on gelatin blocks and allowed the substance to diffuse into the blocks. The blocks were then placed on the cut stumps of the oat seedlings, causing them to curve away from the point of contact. It was now clear that a growth substance did exist and could be extracted. It still had to be isolated and identified, however.

By 1931 two chemists in Holland, F. Kogl and A. J. Haagen-Smit, according to Tukey (44), isolated a substance from human urine which they called auxin, later called auxin a. Another substance named auxin b was isolated from maize oil. A little later the two chemists in connection with H. Erxleben, identified a third substance in urine which was none other than 3-indoleacetic acid, a compound identified in 1885 in the decomposition of proteins. The third substance was called heteroauxin which means the other auxin. Within a year of the identification of 3-indoleacetic acid it was shown by F. W. Went and his associates, and later by Zimmerman and Hitchcock, that when the chemical was sprayed on plants, roots would be induced to form on stems and even fruits. This led to the usage of 3-indoleacetic acid as an aid in rooting cuttings.

Sachs, as pointed out by Tukey (44), as early as 1880 suggested that there were root forming substances present in plants. Tukey further related that Beijerinck in the years 1888 to 1897 had shown that the presence of leaves encouraged root formation. These early

observations are easily explained now in the knowledge that indoleacetic acid is manufactured in the leaves and actively growing parts of the plant.

Thousands of chemicals have been tested for root forming activity. Avery et al (5) termed those few years subsequent to 1935 the "smear era" when synthetically produced hormones were applied to many plants with a wide range of desirable and undesirable results.

Many new discoveries and applications of growth regulators followed in the succeeding years. Some of the more important discoveries as listed by Audus (3), and Mitchell and Marth (28) are: weed control, prevention of growth in stored plant material, prevention of fruit drop, improvement of fruit set, production of seedless fruit, and fruit ripening. Tukey (44) adds to the list of uses, defoliation of plants and regulation of flowering in pineapple.

Preparations are now on the market for the improvement of rooting as well as for many of the other above mentioned uses.

B. Literature on Methyl Ester of Naphthaleneacetic Acid

Naphthaleneacetic acid (NAA) was one of the first and most used chemicals found to induce root growth. This may be noted in the writings of Audus (3), Avery et al (5), Boysen Jensen (7) and Tukey (44). The alpha and beta forms of NAA were first worked with, but in the last few years the methyl ester form has drawn much attention. Since 1939 Guthrie (18, 19), Denny (13), Denny, Guthrie and Thornton (14) as well as many other workers, have done much work with methyl ester of naphthaleneacetic acid (MENA).

Guthrie (19) demonstrated that MENA was effective in controlling aprout growth with whole or cut potato tubers. MENA was more effective than indoleacetic acid (IAA) with whole tubers because of its volatile nature. It was found that MENA has the ability in the vapor form to penetrate plant material and is sufficiently volatile at normal room temperatures. MENA also retarded shriveling of the potato tubers. Denny and Guthrie (14) found that the length of inhibition was dependent on the amount of chemical used for a given amount of potato tuber.

Marth (26), in trying to inhibit growth of roses in common storage, found that MENA would control growth for forty to sixty days. MENA was effective when applied at 70° F., 40° F., and 32° F., but longer periods of application were necessary at lower temperatures to obtain good inhibition.

Sawyer and Dallyn (36, 37, 38) reported on results of sprout control on potato tubers by vaporizing chemicals with the ventilation equipment of the storage house. MENA was effective at all temperatures between 40° F. and 70° F. Onions were also treated in a similar manner with MENA in amounts up to the amount effective with potatoes. Instead

of inhibiting, sprouts were stimulated. This was explained by the fact that the onion sprout arises from meristematic tissue deep within the bulb. Apparently only a small amount of the chemical reached the growing point, and instead of inhibiting, it stimulated growth.

Findlen (16) reported that MENA was more effective when applied to an unsprouted condition than it was after sprouts appear. Potatoes that are desprouted (sprouts broken off) show increased inhibition. This is probably because the chemical enters easily at the broken sprout surfaces.

Isbell (21), tested the commercial preparation Barsprout (a dust containing 2.2% MENA) and found that it did not completely prevent shriveling or sprouting. Some rotting was also attributed to the treatment but enough potatoes were improved in quality to justify treating them.

Ellison and Smith (15) made field sprays of MENA to potato plants and obtained a successful degree of sprout inhibition with the stored tubers. Tubers which were inhibited with the sprays were planted the following year and no differences in the yields were found.

Acker (1) studied the effect of MENA on three varieties of Lilium grown from bulbs treated with the chemical. Lower concentrations of the chemical induced earlier flowering than non-treated. Treated bulbs produced larger flowers and more bulblets. The highest concentrations caused the plants to be stunted. The higher the concentration of the chemical the greater the stunting.

Carolus et al (10), in working with storage life of cauliflower concluded that MENA lessened loss of weight and retarded the development

of the abcission layer in leaves. It is already known, according to Audus (3) and Avery et al (5), that auxin is lacking or present in very small quantities when the abcission layer is formed.

Thimann (43) relates the idea that auxin accelerates growth up to a certain point, and beyond this point inhibition begins. The greater the auxin level beyond the acceleration point, the longer the inhibition. Since it is a derivative of naphthaleneacetic acid (NAA), a compound having all the properties of an auxin, MENA would be expected to perform in a manner similar to the action of other auxins.

The above cited research points to the fact that MENA is a true auxin.

C. Literature on Maleic Hydrazide

The chemical compound, 1,2, dihydro-3,6, pyridazine-dione commonly known as maleic hydrazide (MH), has been the subject of much experimentation. MH will cause some changes in plants similar to that caused by MENA plus having certain abilities not found with MENA. Audus (3) and Avery et al (5) say that MH has the ability to overcome apical dominance, to cause male sterility in certain crops, to inhibit bud growth, to cause leaf and fruit abscission, to hasten the production of seed stalks and flowers, to inhibit the growth of certain weeds and to delay the maturity and ripening of fruit.

The outward changes in plant form caused by MH are well known. It is, however, the inward changes that are in much discussion.

Isenberg (23) reported that treatments with MH to immature onions caused puffy bulbs. Greulach and Haesloop (17) determined that very low concentrations of MH inhibited mitosis but did not interfere with cell enlargement. This could account for the puffy condition in onions found by Isenberg.

Crandall (11) applied MH to Delicious apple trees to determine the effects on the storage quality of the fruit. Sprays four weeks before harvest gave significant increase in firmness for the first three weeks of storage. Sprays one week before harvest gave no similar results, which indicates slowness in the ability of the chemical to be absorbed. The firmness caused MH may be explained by work done by Isenberg and co-workers (22). They found that MH interferes with one or more enzymes in the respiration cycle.

Smock et al (40) had earlier reported about the same effects as obtained by Crandall. Smock also reported that respiration was sometimes reduced by treatment with MH.

Brody and Francis (8) tested five chemicals for ability to hold down rate of respiration in cut asparagus. Only MH showed promise in reducing respiration and retaining tenderness. Southwick and Lachman (41) found that respiration rates were reduced in harvested tomatoes with MH treatments.

Numerous other workers have reported success with MH as a growth inhibitor. Schoene and Hoffman (39) call MH a unique growth regulant and terms its effect "pronounced but temporary." The period of inhibition was found to be directly proportional to the concentration used. Mitterer et al (47, 48) reported growth inhibition and improved storage quality of onions, carrots, and potatoes with MH applied as foliage sprays before harvest. Most other chemicals used caused undesirable formation of callus tissue and proliferations.

Herman et al (20) and Rao et al studied time of application of MH sprays to potato plants and the effect on the stored tubers. Sprouting decreased with increased concentration. Best inhibition was obtained with applications three to six weeks before harvest. Later applications were less effective in holding down sprouting.

Marshall and Smith (25) worked with both MH and MENA to reduce sprouting on potatoes. Their methods of application point out the relative ease with which the two chemicals penetrate the tubers. MH was ineffective as a dip but very effective when MH-soaked toothpicks were inserted half-way into the tubers. Mena was effective with both methods.

Strudemeyer (42), reporting the effects of MH on the anatomical structure of Easter lilies, stated that an inhibition of growth and failure to differentiate flower buds followed treatments of 0.2% concentrations of the chemical. Leaves were thicker, and cells were larger

and more loosely arranged in spongy parenchyma.

Audus and Thresh (4) report MH as a very strong inhibitor of root growth. The inhibition was stated to be due to interference of the meristematic phase of cell growth. Currier et al (12) also list cessation of cell division among the effects of MH on plant growth. Audus and Thresh (4) also noted that MH has the action of removing apical dominance. The action was suggested to resemble that of an anti-auxin. Leopold and Klein (24) also suggested that MH is an anti-auxin. They state that in general growth inhibitors do not cause lateral buds to develop. As an anti-auxin MH would be expected to inhibit when auxin is lacking, but not when auxin is present in sufficient amount.

Naylor and Davis (30) call MH an auxin antagonist in its effect of interfering with internodal elongation and removing apical dominance. Loss of apical dominance was successful with a wide range of plants. It was suggested that MH is possibly an indoleacetic acid antagonist.

Mastalerz and Campbell (27), and Powell and Andresen (32) were successful in breaking apical dominance with Chrysanthemum, but abnormal leaves and flowers resulted. Beck et al (6) made studies with MH to reduce labor of pinching carnations. Laterals were induced to grow, but flower development was slower in those treated. Thimann (43) states the theory of the inhibition of laterals is based on the excess of growth substances present in the stems of plants. When the terminals are removed the production of the substances ceases and the laterals are allowed to grow. It is suggested that MH reduces the indoleacetic acid oxidase activity, and this reduction lowers the auxin level and allows lateral buds to grow.

Patterson (31) made foliage sprays of MH to two varieties of sweet potatoes one month before harvest. Higher concentrations caused a reduction in slip production with bedded potatoes. Lower concentrations caused a loss of proximal dominance and allowed a normal slip production. One variety showed an increase in slip production.

Molero (29) was successful in destroying apical dominance in southern peas with MH sprays. The size and number of pods increased with treatment but no harmful effect with respect to germination or seedling survival, was found.

Callaghan and VanNorman (9) found an increase in photosynthesis in lettuce and swiss chard after foliar sprays of MH.

Salisbury (35) found that a number of chemicals would inhibit the flowering of cocklebur. MH was one of the chemicals that would inhibit flowering regardless of time of application before formation.

There is some indication that certain growth regulators react directly with sulphydryl groups and in this manner inhibit some of the essential enzymatic reactions. This theory was presented by A.C. Leopold, according to Wain and Wightman (45), at the 1955 International Conference on Plant Growth Substances, held at Wye College, London. Leopold also pointed out that it was Thimann's idea that sulphydryl inhibitors occuring naturally in tissue might be protected against auxins.

Weller et al (46) stated the belief that MH acts as a growth inhibitor by reacting with certain essential thiol (syn. sulphydryl) compounds. It was confirmed that maleic acid does react with thiols to form additional compounds but MH does not react the same under similar conditions. Further studies showed that there was no enzyme system capable of catalyzing the reaction or converting the MH into a compound

that would add to the thiol group. This may help support the theory that MH is an indoleacetic acid antagonist or that it reduces oxidase activity as pointed out earlier.

METHODS AND MATERIALS

This study began in August of 1953. Storage of the tubers and all work connected with storage and planting took place at the University of Georgia horticultural farm at Athens, Georgia. All laboratory work was performed in one of the Horticulture Department laboratories. Pre-harvest foliage sprays were made in the commercial fields at Todd's Dahlia Farm near Suches, Georgia in Union County (Fig. 1.). After harvest all tubers were brought to Athens for storage.

The Dahlia variety Robin Hood was used in the experiment because of its uniform growth and known ability to produce moderate amounts of tubers.

After a review of the literature, two chemicals, methyl ester of naphthaleneacetic acid (MENA) and maleic hydrazide (MH), were chosen for the tests. Concentrations of 500, 1000 and 3000 ppm were used with the two chemicals in both pre-harvest and post-harvest treatments.

A row was marked off from north to south into four blocks and marked respectively A, B, C, and D. Treatments in each block were randomized and each plant tagged according to the treatment it had been assigned to receive. Plants whose tubers were to receive post-harvest treatments were also labeled at this time. The same randomization was maintained throughout storage.

An individual spray treatment consisted of three plants. A special cardboard chamber was made to fit over these three plants, to facilitate applying the spray and keeping the surrounding plants from being affected. Spraying was done with new hand fly sprayers, using separate sprayers for the two chemicals.

The time of pre-harvest foliage treatments was September 17.

Fig. 1. Field of dahlias at the time of pre-harvest (foliage) treatments. White markers show the length of one block.

twenty-five days before the first light frost, thirty-one days before the first killing frost.

All tubers were harvested November 1. The dead tops were cut off near the ground with a sharp knife and removed, leaving the labels attached to the stumps. Each clump was then lifted out of the ground with spades, being careful not to break the necks of the tubers. Excess soil was removed from between the tubers by gently tapping the stump of the old stalk with a light instrument while holding the clump in one hand. The long stump of the old stalk was removed from the tuber clump with the aid of a light axe and chopping block. Labels were then securely attached to one of the larger tubers.

After the tubers were transferred to Athens, they were washed, trimmed, and treated with a fungicide (Semesan) dip to retard rotting in storage. After the tubers were allowed to dry off for about 48 hours, the chemical inhibitors were applied to tubers according to the treatment they had been assigned to receive at this time.

Chemicals were applied with hand sprayers in a manner similar to the pre-harvest foliage sprays. The clumps of tubers were sprayed until their surfaces were thoroughly wet.

Tubers of each treatment were weighed and placed in boxes filled with moist peat. The boxes were arranged in storage as shown in figure 3, according to the pre-determined order of randomization.

The building in which the tubers were stored, shown in figure 2, is the sweet potato storage house at the University of Georgia horticultural farm. The south room was used, and no other crop or material was in the same room.

Fig. 2. Storage house used to store the dahlia tubers.

Fig. 3. Inside storage house, showing arrangement of boxes in which dahlia tubers were stored. Box on left shows tubers stored in one box. Box on right shows peat after tubers have been covered.

A temperature range of 55°-60° F. was maintained with the belief that it would be sufficient to start sprouting on the least inhibited tubers. Sprouting was found to be too slow at the above temperature so, beginning the last of February, the temperature was gradually raised. First signs of growth appeared at 62° F. one week later. By the last of March temperatures were ranging as high as 68° F. and sprouting was general on the control tubers as well as on many of the treatments.

Sprouts were counted and measured on March 8, April 1, and May 1, to determine any inhibitory effect due to the chemical treatments. Sprout lengths were recorded in millimeters. Dormant eyes were not counted since there was no known way to detect them accurately. Sprouts were counted only where new growth could be detected by observation with the naked eye.

At the end of the storage period all tubers were weighed, and weights were recorded in grams. These weights were compared with the original weights to determine any fluctuations that might have occured during storage.

Planting of field plots was done on May 23. Excessive rains for three weeks following planting caused much rotting and loss of tubers. Because of the reduced number of plants, a statistical analysis would have been difficult. However, since two or more plants of every treatment survived, observations of growth character were made.

Experiments were set up in the laboratory to determine rates of sprout and root growth. In the experiment all sprouts were cut off to induce resprouting. The tip of the root end was also cut off to remove all root initials and allow new roots to be formed at the cut surface. Each tuber was placed at the mouth of a 300 ml flask which

was filled to the neck with distilled water. Paper towels were used to wick moisture from the flask to the tuber, which was about one inch above the water level. Measurements were made of root and sprout lengths to determine if any inhibitory effect was still present due to the treatments.

RESULTS AND DISCUSSION

A. Effects of pre-harvest foliage treatments

1. MENA Treatments

It was found in this experiment that the length of the individual sprout was not affected on April 1, but on May 1, an increase was recorded with all three concentrations of MENA. This can be clearly seen in figure 4. This is the reverse effect that is quite often obtained when testing for proper concentrations or method of application. It is possible that a higher concentration or a better method of applying the chemical would give better control of sprouting.

There was a slight reduction of total sprout growth per clump, but this reduction is not significant since this difference was due to a reduced number of sprouts. Figures 5 and 6 show these slight differences. It may also be noted on figure 5 that by May 1, treated tubers showed an increase over the controls even with a reduced number of sprouts per clump.

Figure 7 shows the effects of MENA on sprouting of tubers. This picture was taken at the end of the storage period. As you may note there is no striking difference between the control tubers and the ones that received foliage sprays of MENA.

Figure 8 shows plants grown after the storage period. The check plant in the figure was about 18 inches tall compared with 12 inches for the plants from the MENA treatments. It should be pointed out that the check plant came up 10 to 15 days earlier than the other plants. There was no abnormal growth characteristics noted with any treatments other than slowness of sprouts to emerge.

Laboratory germination studies were made primarily to observe

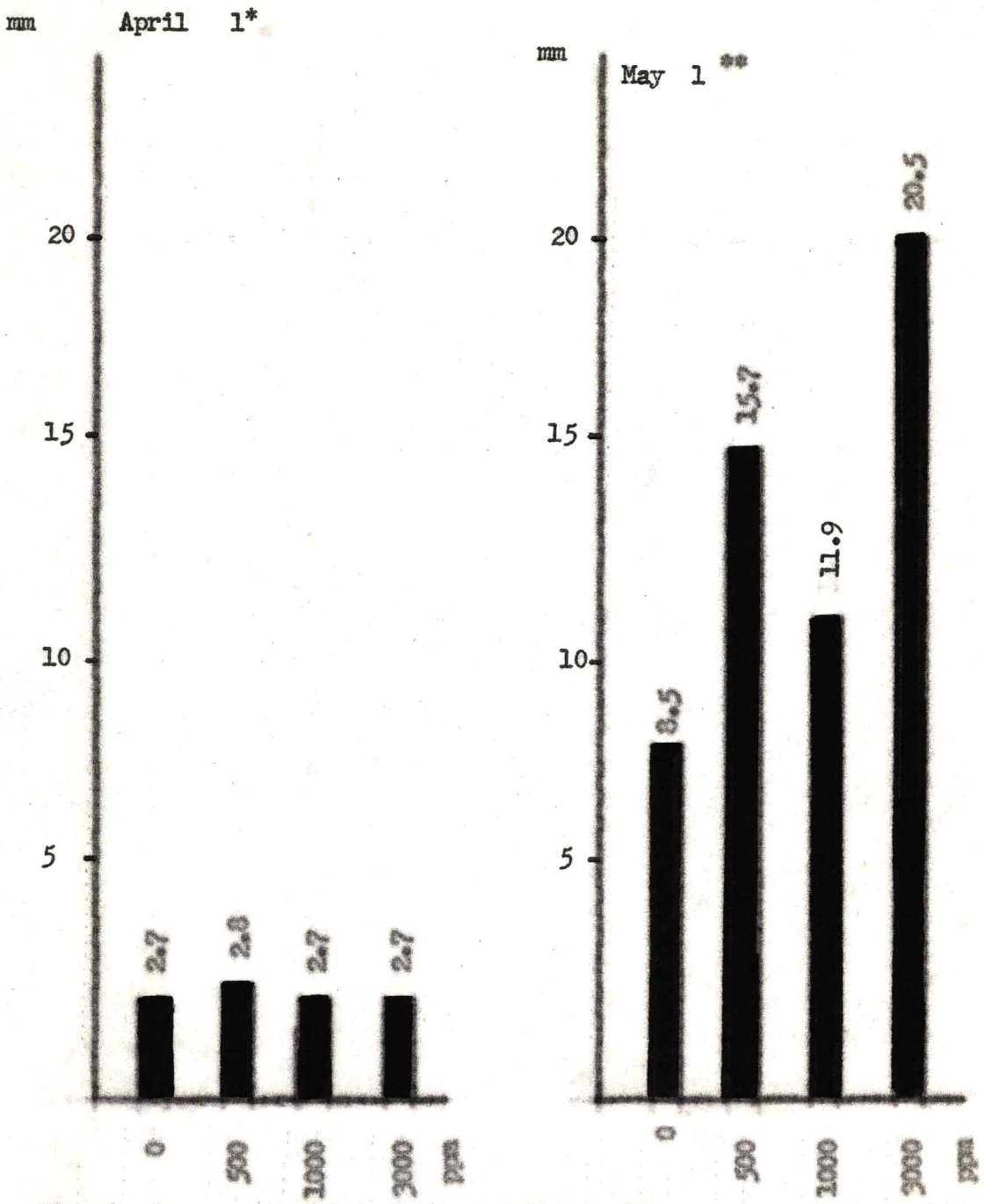

Fig. 4. Average sprout growth of dahlias with pre-harvest (foliage) treatments using MENA.

* Values represent measurements taken from 12 tuber clumps having one to two sprouts per clump.

**Values represent measurements taken from 12 tuber clumps having two to four sprouts per clump.

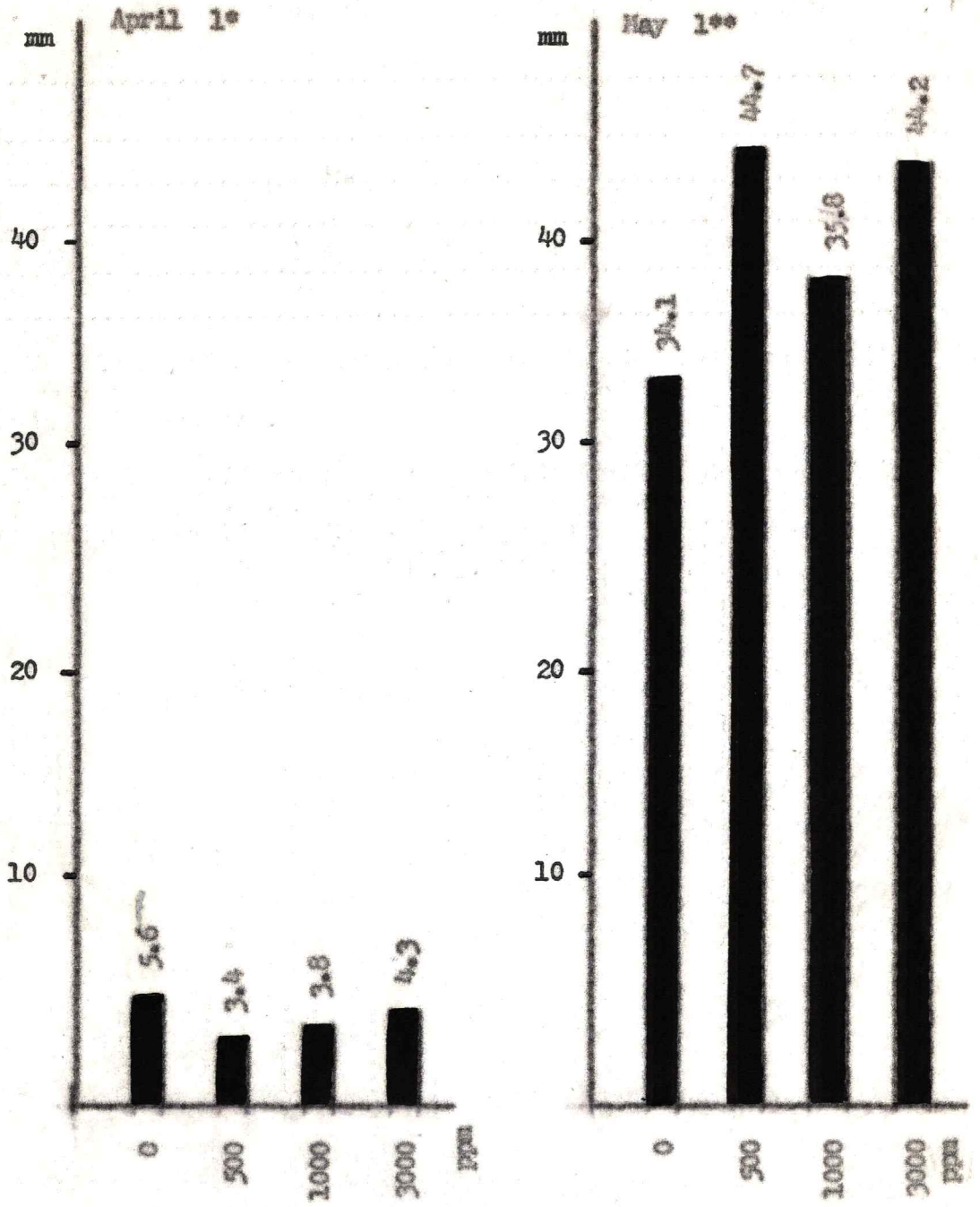

Fig. 5. Total sprout growth per tuber clump with pre-harvest foliage treatments using MENA.

* Values represent measurements taken from 12 tuber clumps having one to two sprouts per clump.
** Values represent measurements taken from 12 tuber clumps having two to four sprouts per clump.

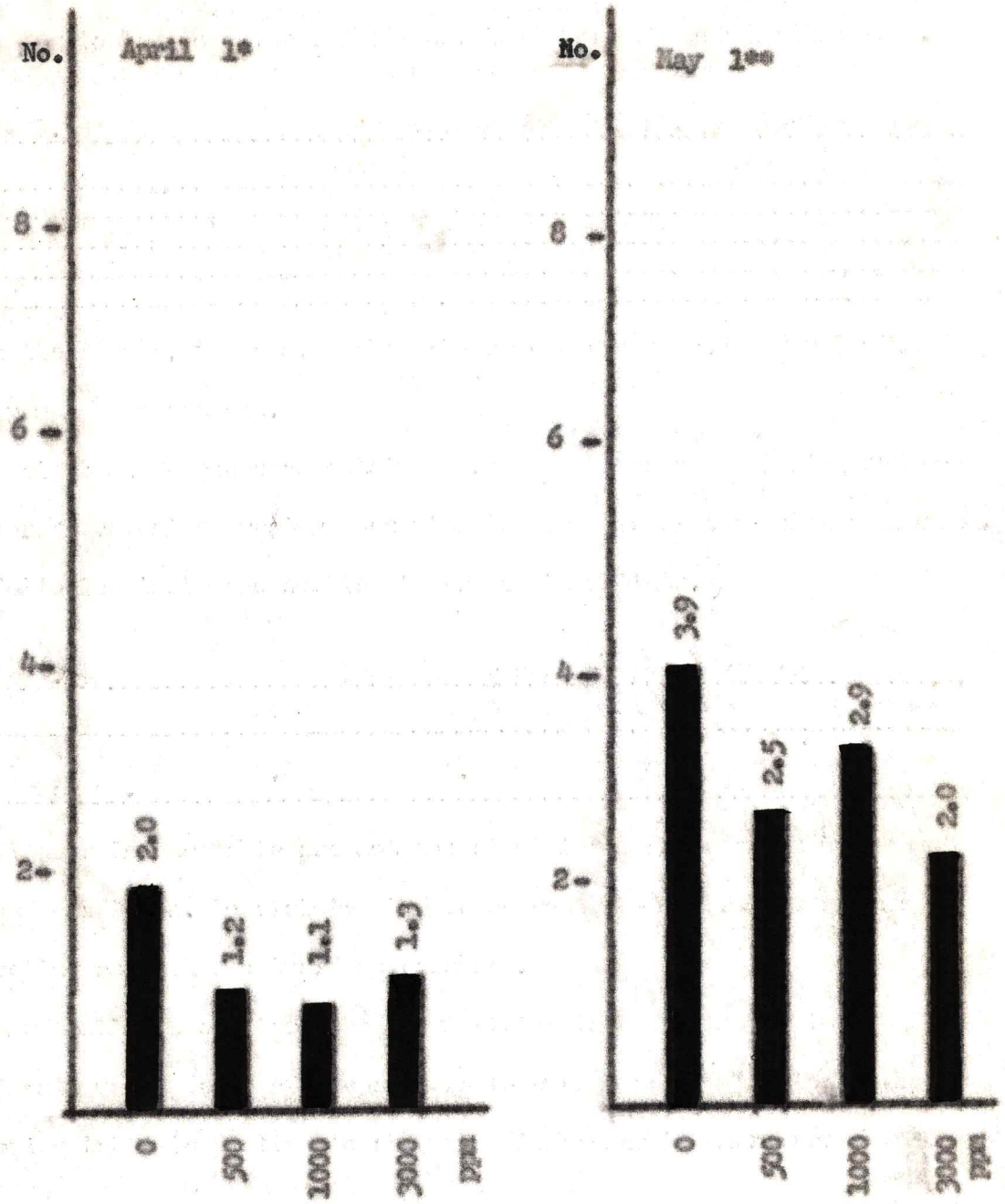

Fig. 6. Average number of sprouts per tuber clump of pre-harvest (foliage) treatments using MENA.

* Values represent measurements taken from 12 tuber clumps having one to two sprouts per clump.
** Values represent measurements taken from 12 tuber clumps having two to four sprouts per clump.

Fig. 7. Tubers of pre-harvest treated plants at the end of storage. 1. 500 ppm MENA, 2. 1000 ppm MENA, 3. 3000 ppm MENA, Check. No treatment.

Fig. 8. Representative plants in field test planting after storage. 1. 500 ppm MENA, 2. 1000 ppm MENA, 3. 3000 ppm MENA, Check. no MENA.

relative root growth, however sprout growth was also recorded. Fig. 9 shows some of the tubers used in the germination test and the relative difference in root and sprout growth caused by chemical treatments. The following table shows the results obtained from the germination test.

Table 1. Average Growth (Lab. germination test)

	Roots (mm)	Sprouts (mm)
500 ppm MENA	34	11
1000 ppm MENA	101	15
3000 ppm MENA	148	19
Check	102	19

As in the figure, the above table shows accelerated root growth with 3000 ppm MENA treatment.

Weight differences as obtained from weighings at beginning and end of storage reveal a smaller loss with treated tubers than with untreated. The following table shows this difference in weights.

Table 2. Weight differences of stored tubers - MENA treat.

	Check	500 ppm	1000 ppm	3000 ppm
Loss per 100 g of tuber wt.	3.6	2.3	2.1	3.1

The figures in the table are not too significant since all tubers were in good condition. No visible difference could be determined so far as shriveling and other ourward appearances.

As mentioned earlier, the only detrimental effects due to MENA treatments was a delay of the sprouts to emerge after planting. The following table is plotted to show the difference in emergence dates.

Table 3. Dates of Emergence -- Planting after storage - MENA treat.

Dates	Check	500 ppm	1000ppm	3000 ppm
June 8	x		x	
" 11	x			
" 14	x	x		xx
" 21-23		xx		
" 26-30			xxx	

Fig. 9. Germination test of pre-harvest MENA treatments. 1. 500 ppm MENA, 2. 1000 ppm MENA, 3. 3000 ppm MENA, Ck. No treatment.

2. MH Treatments

MH, according to the previously reviewed literature, apparently has more uses and has been used more as a growth inhibitor than has MENA. According to the literature, MH has given best results as a growth inhibitor when applied as foliage sprays. However, the literature reveals that excellent growth inhibition can be obtained with MH if some type of injection method is used to apply the chemical. This may point to the consideration that MH has poor qualities for penetrating plant material.

It was found in this experiment that sprout growth was accelerated by foliage sprays of MH using 500 ppm and 3000 ppm. This may be noted in figure 10 which shows average sprout growth, and in figure 11 which shows total sprout growth per tuber clump. MH treatments using 1000 ppm gave a decrease in sprout growth, which was not expected since the other concentrations both gave increases. In no case did tubers of this treatment compare in growth as great as the control tubers of the block concerned. In one block the clumps of tubers showed no signs of growth when the first sprout measurements were taken. It was noted that the peat packed around the tuber clumps was slightly drier than other boxes examined. However, even discounting this box, the treatment as a whole still would not have shown an increase over the control tubers.

The results of treatments on average number of sprouts followed a more normal pattern, as shown in figure 12. The slight increase with 500 ppm on April 1 counts is not too significant since this much variation could take place normally. There was only one instance where the 500 ppm treated tubers gave a larger sprout count than control tubers.

Figure 13 illustrates the effect of MH treatments on sprouting

of the tubers. All boxes contain a number of long sprouts, however close observation is necessary since some of the sprouts are darker colored and do not show up well in the picture. It may be noted that all tubers are in good condition so far as being shriveled or dried out.

Plants from the field planting, illustrated in figure 14, gave equal or superior growth as compared to control plants. No abnormal growth effects were noted with the plants in the field test. Emergence of the sprouts was much better than with pre-harvest MENA treatments. In this case, with the pre-harvest MH treatments, only three plants came up after the control plants.

Figure 15 illustrates the results of the laboratory germination test. It may be noted that 500 ppm MH treatment gave root growth normal in length but fewer in number. Treatments of 1000 ppm caused roots to be long and thin. MH treatments using 3000 ppm concentrations caused roots to be slightly thicker and longer than control tubers. The following table gives the results of the measurements taken from the laboratory germination test.

Table 4. Average Growth (Lab. Germination test)

	Roots (mm)	Sprouts (mm)
500 ppm MH	101	20
1000 ppm MH	193	31
3000 ppm MH	110	34
Check	101	35

The significant fact here was that there was no inhibition of root growth with the tubers which received MH treatments.

Weight differences as obtained from weighings at beginning and end of storage reveal a smaller loss with treated tubers than with untreated, except for the 1000 ppm MH treatment.
The following table shows this difference in weights.

Table 5. Weight differences of stored tubers - MH treatments

	Check	500 ppm	1000 ppm	3000 ppm
Loss per 100 g of tuber wt.	3.6	1.9	4.2	2.4

It may be noted that the tubers that showed the greatest loss of weight are the same ones that gave the smallest amount of sprout growth. It is reasonable that the tubers making the most sprout growth are also making more root growth. If this was the case tubers of treatments 500 ppm and 3000 ppm could have replaced some of the lost moisture by taking water from the moist peat in which they were packed.

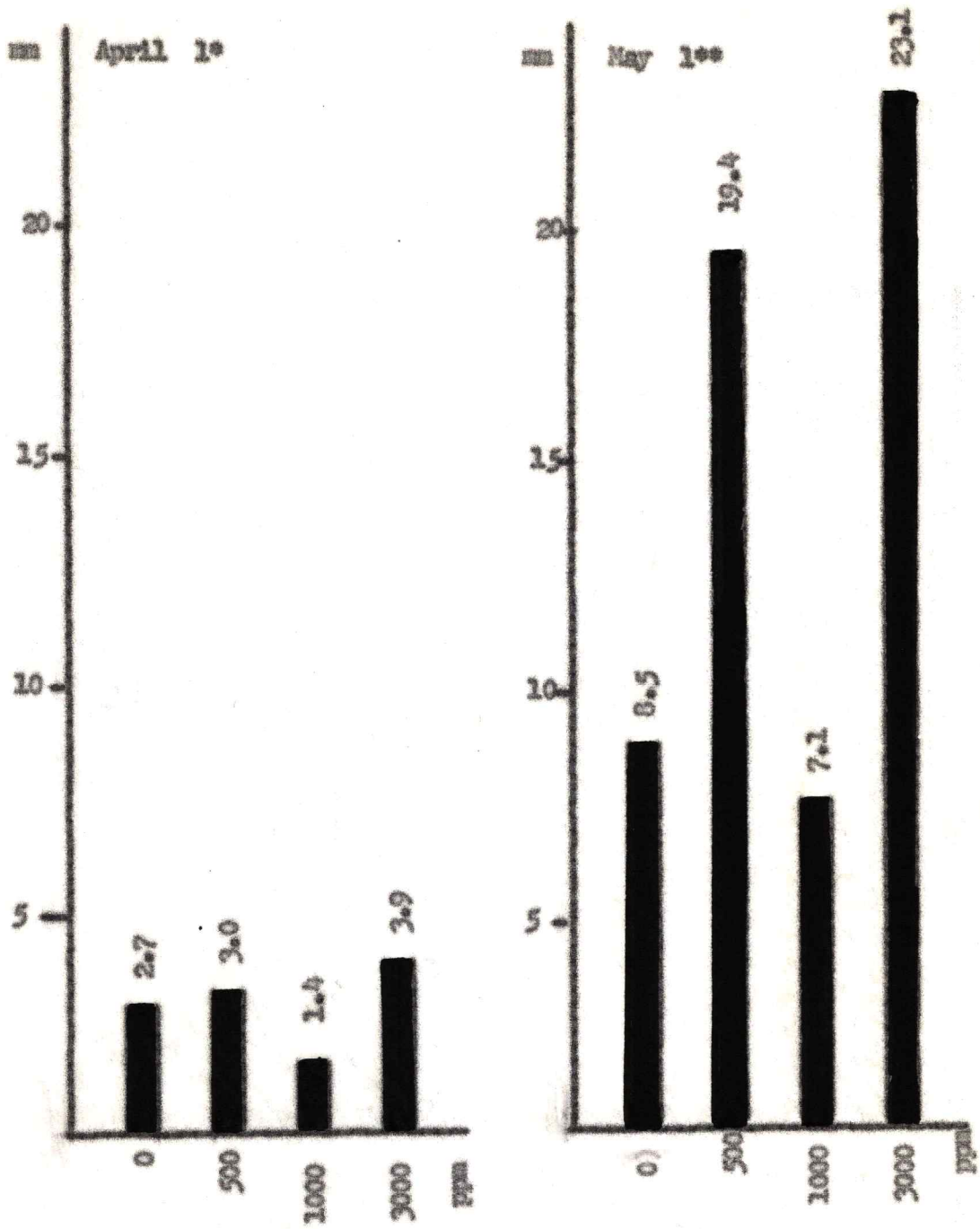

Fig. 10. Average sprout growth of dahlias with pre-harvest (foliage) treatments using MH.

* Values represent measurements taken from 12 tuber clumps having one to two sprouts per clump.

** Values represent measurements taken from 12 tuber clumps having two to four sprouts per clump.

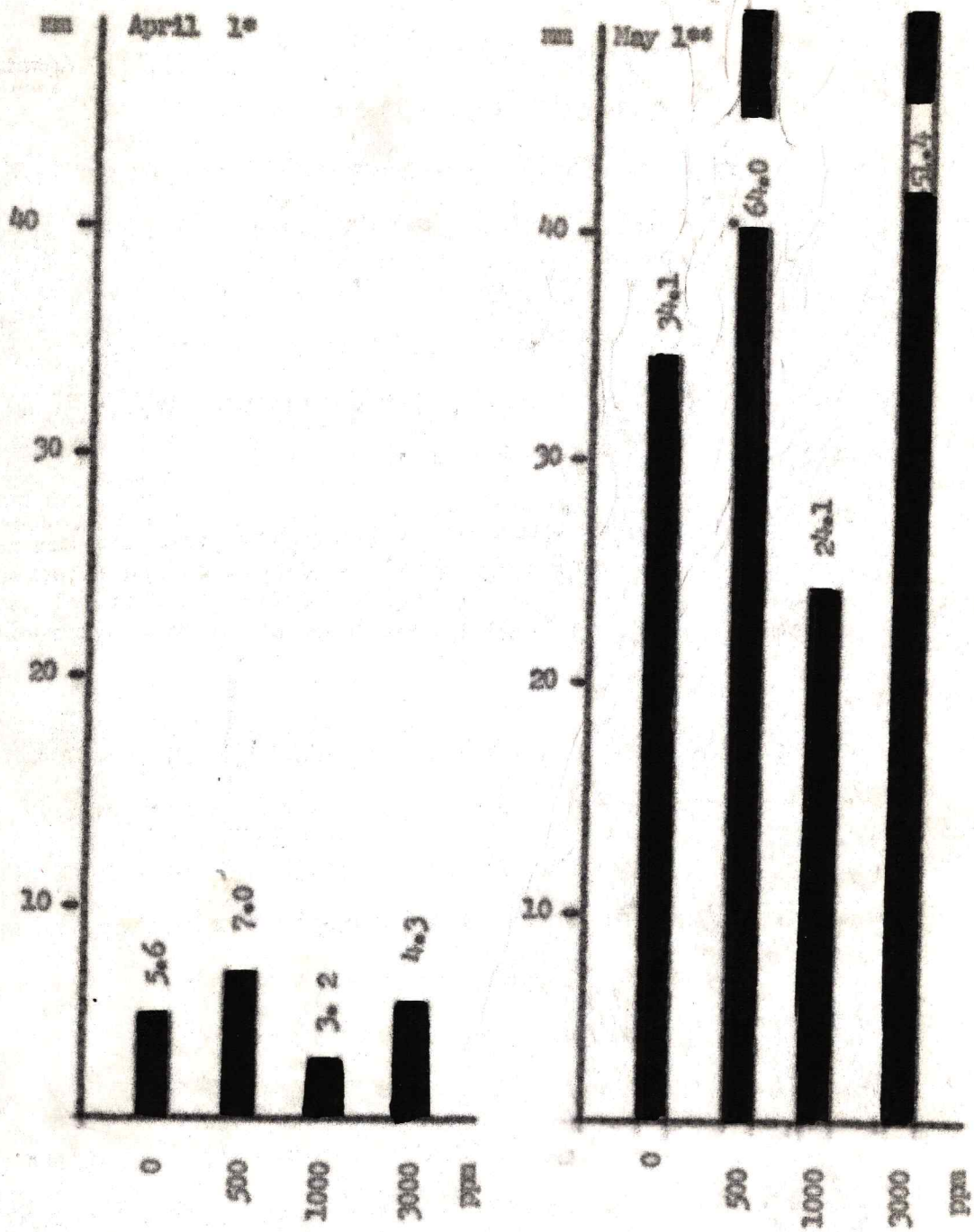

Fig. 11. Total sprout growth per tuber clump with pre-harvest (foliage) treatments using MH.

* Values represent measurements taken from 12 tuber clumps having one to two sprouts per clump.

** Values represent measurements taken from 12 tuber clumps having two to four sprouts per clump.

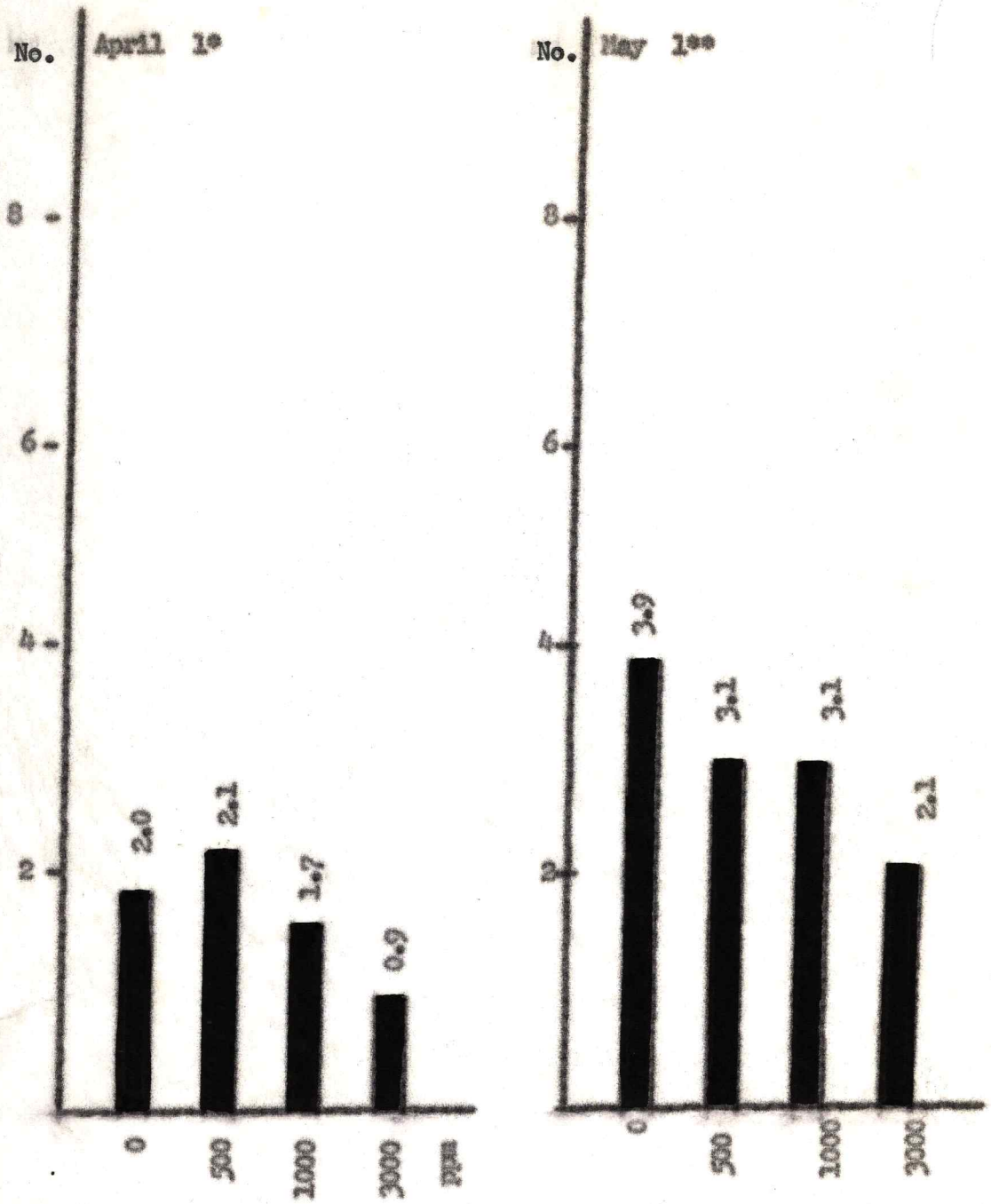

Fig. 12. Average number of sprouts per clump of pre-harvest (foliage) treatments using MH.

* Values represent measurements taken from 12 tuber clumps having one to two sprouts per clump.

** Values represent measurements taken from 12 tuber clumps having two to four sprouts per clump.

Fig. 13. Tubers of pre-harvest MH treated plants, at the end of storage. 4. 500 ppm MH, 5. 1000 ppm MH, 6. 3000 ppm MH, Check. no MH.

Fig. 14. Illustrations of plants in field test planting after storage. 4. 500 ppm MH, 5. 1000 ppm MH, 6. 3000 ppm MH, Check, no MH.

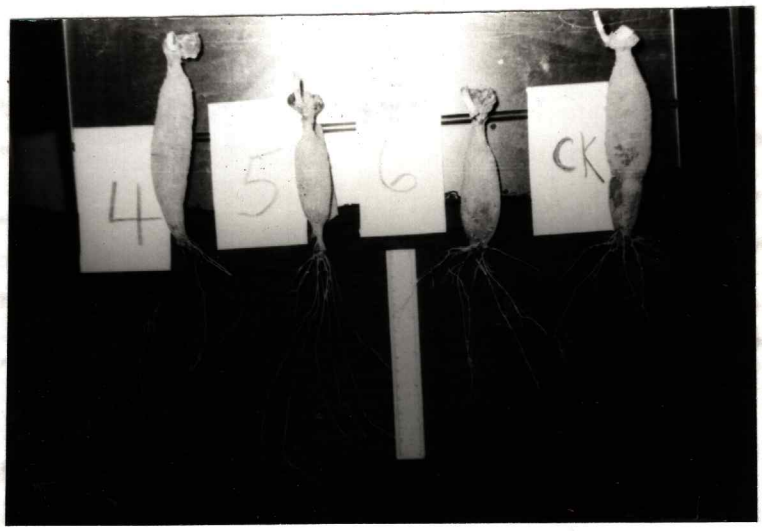

Fig. 15. Germination test of pre-harvest MH treatments. 4. 500 ppm MH, 5. 1000 ppm MH, 6. 3000 ppm MH, Check. no MH.

B. Effects of Post-harvest Tuber Treatments

1. MENA Treatments

Since it is a volatile form of the auxin, naphthaleneacetic acid (NAA), MENA has been used extensively to obtain better penetration of plant material. It is also desirable since it leaves no visible residue on the treated stock.

MENA is now widely accepted and available in commercial preparations for treating potato tubers or other root crops; but has not been recommended for treating stock intended for seed purposes.

The average length of sprouts was not affected greatly with the exception of 3000 ppm treatment on May 1, as shown in figure 16. The real test on inhibition is the total sprout growth per clump. Figure 17 shows quite a significant decrease of sprout growth . April 1 figures in figure 17 indicates that 500 ppm concentration is sufficient for good inhibition. Possibly a smaller concentration would be more suitable and would give quicker recovery over the inhibitory effect. It may also be noted in figure 17, that by May 1 all treatments were growing quite well. The amount of growth on the treated tubers was inversely proportional to the amount MENA used with the treatments.

Before any recommendations are made further test should be made using 500 ppm and less to determine exactly what concentration is best for good inhibition. It should be noted that treatments also reduced the number of sprouts. With a variety of dahlias that has only a few eyes or sprouts, this could be serious. Possibly some concentration lower than 500 ppm would give good control of sprout growth and not affect the number of sprouts at planting time. Figure 18 shows the reduction of sprout number caused by MENA treatments.

Figure 19 illustrates the good condition of all the tubers at the end of storage. A number of sprouts are evident on the check box, and several are visible in boxes 8 and 9 which are 500 ppm and 1000 ppm treatments. Sprouts are quite small and hard to find on the tubers given 3000 ppm MENA treatments.

Fig. 20 illustrates the recovery to growth after planting in the field test. Plants from tubers given 500 and 1000 ppm MENA have made good recovery, whereas 3000 ppm seems to still have an inhibitory effect. The only other growth effects noted due to the chemical treatments was a delay in sprouts to emerge after planting. The following table is plotted to show the delay of the plants to come up.

Table 6. Dates of Emergence -- Planting after storage - MENA treat.

Dates	Check	500 ppm	1000 ppm	3000 ppm
June 8	xx			
" 10	x		x	
" 13-14			x	x
" 21		x		
" 23		x		x
" 26		xxx	x	x
" 30m			x	
July 4			x	

The table indicates that some of the treated plants were as much as three to four weeks later coming up than the check plants.

Figure 21 illustrates the results of the laboratory germination test. Treatments of 1000 ppm and 3000 ppm caused a slight increase in sprout length and number. Sprout growth was not affected greatly. The following table shows more exactly the differences in root and sprout growth.

Table 7. Average growth (Lab. germination test)

	Roots (mm)	Sprouts (mm)
500 ppm MENA	88	28
1000 ppm MENA	90	25
3000 ppm MENA	108	31
Check	84	34

It should be noted that there was no inhibitory effect noted with the tubers in the germination tests. The tubers from 3000 ppm treatments gave good sprout growth and even promoted extra root growth, whereas in other tests an inhibitory effect was noted.

Weight differences, as obtained from weighings at beginning and end of storage, revealed a greater loss with treated tubers than with untreated. The following table shows this difference in weights.

Table 8. Weight differences of stored tubers - MENA treatments

	Check	500 ppm	1000 ppm	3000 ppm
Loss per 100 g of tuber wt.	3.6	4.4	3.4	4.1

The difference in weight here is probably due to the fact that the treated tubers were not doing much growing so was not taking up sufficient moisture to replace that lost by respiration or evaporation. However, the differences found in the above table is not too considerable.

MENA applied as a post-harvest treatment seems to be the most promising for chemical control of sprout growth on dahlias. More tests are needed, however, before any definite recommendations can be made.

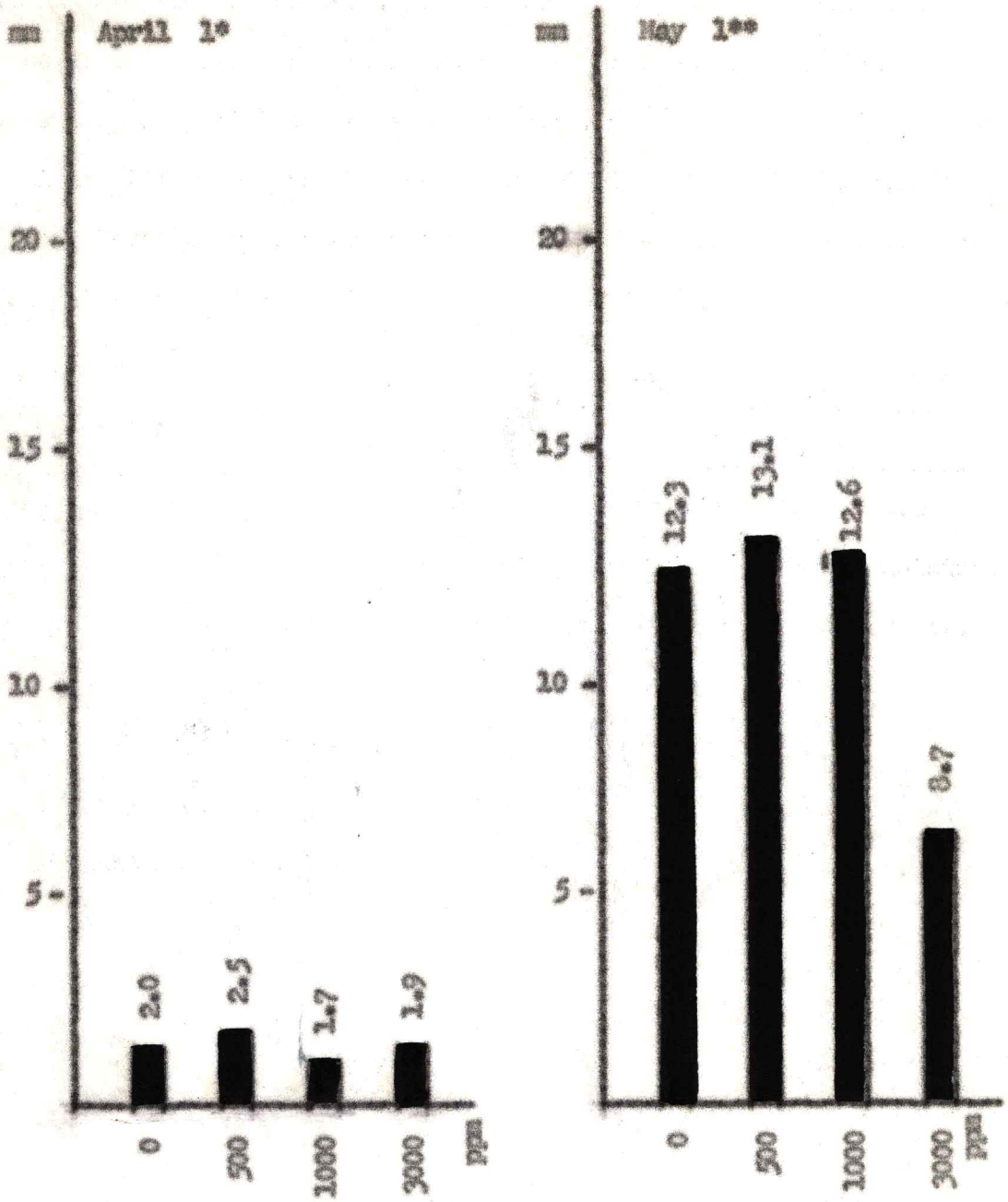

Fig. 16. Average sprout growth of dahlias with post-harvest (tuber) treatments using MENA.

* Values represent measurements taken from 12 tuber clumps having one to two sprouts per clump.

** Values represent measurements taken from 12 tuber clumps having two to four sprouts per clump.

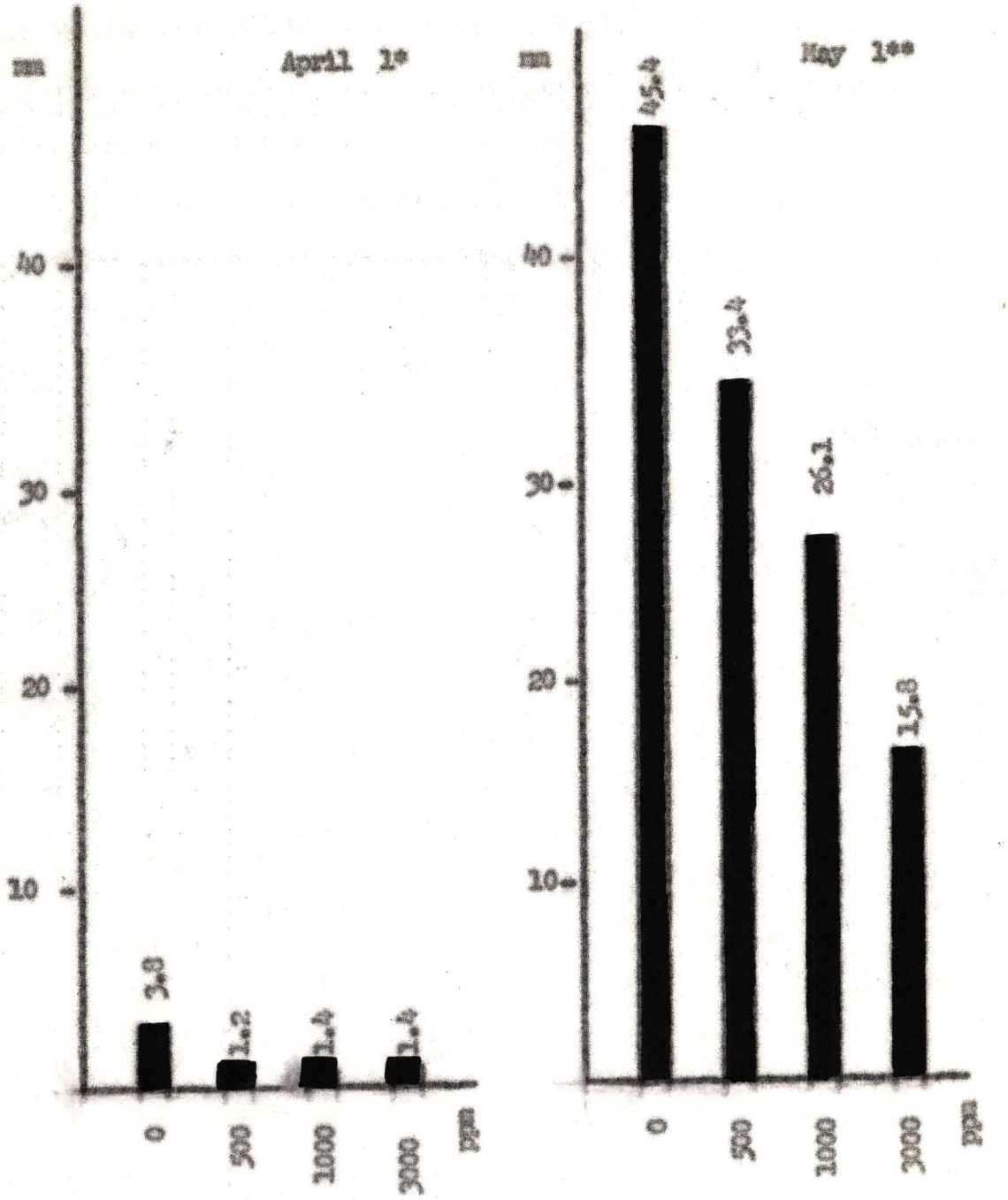

Fig. 17. Total sprout growth per tuber clump with post-harvest (tuber) treatments using MMIA.

* Values represent measurements taken from 12 tuber clumps having one to two sprouts per clump.

** Values represent measurements taken from 12 tuber clumps having two to four sprouts per clump.

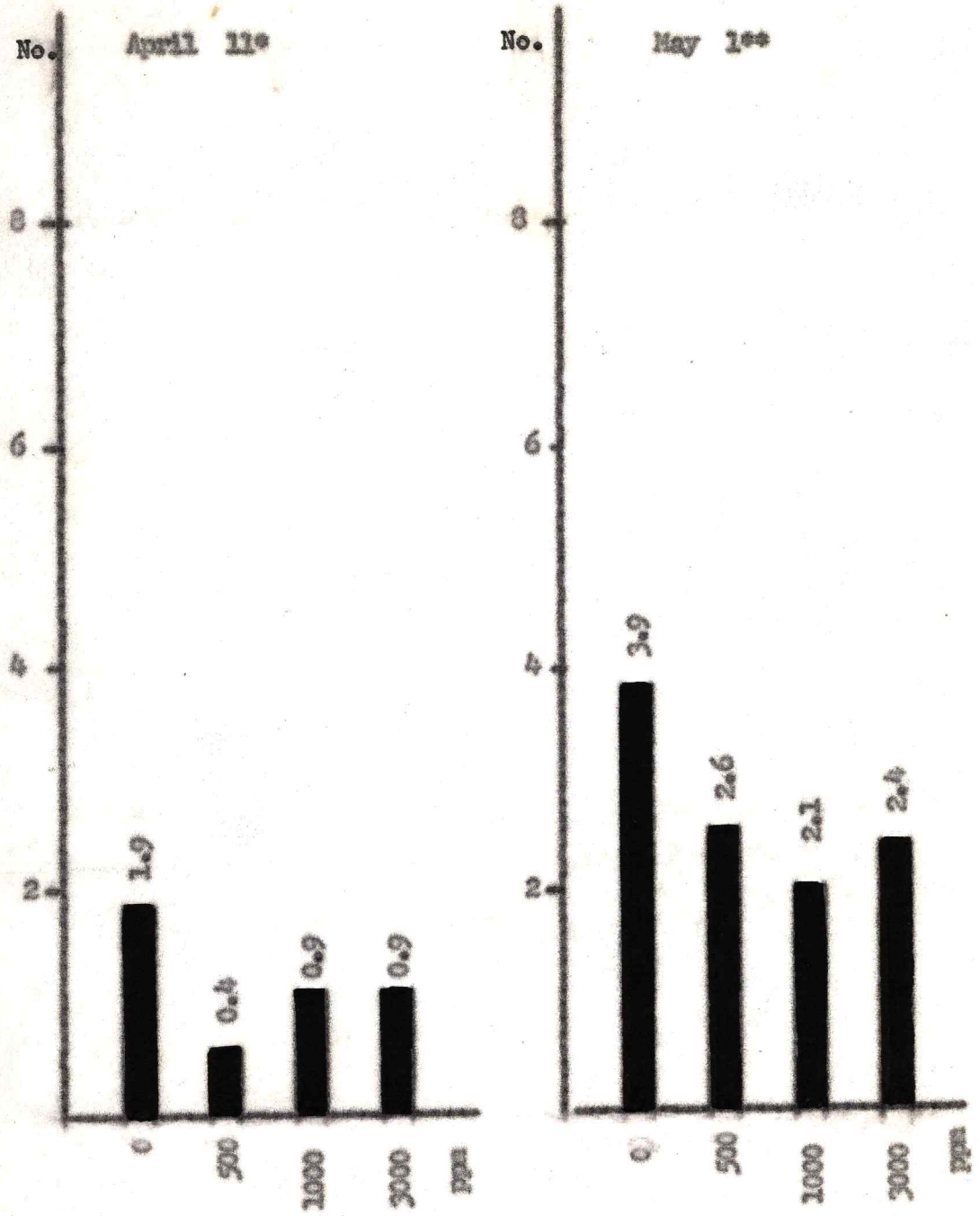

Fig. 18. Average number of sprouts per clump with post-harvest (tuber) treatments using MENA

* Values represent measurements taken from 12 tuber clumps having one to two sprouts per clump.

** Values represent measurements taken from 14 tuber clumps having two to four sprouts per clump.

Fig. 19. Tubers of post-harvest MENA treated plants, at the end of storage. 8. 500 ppm MENA, 9. 1000 ppm MENA, 10. 3000 ppm MENA, Check. no MENA.

Fig. 20. Illustrations of plants in field test planting after storage. 8. 500 ppm MENA, 9. 1000 ppm MENA, 10. 3000 ppm MENA, Check. No MENA.

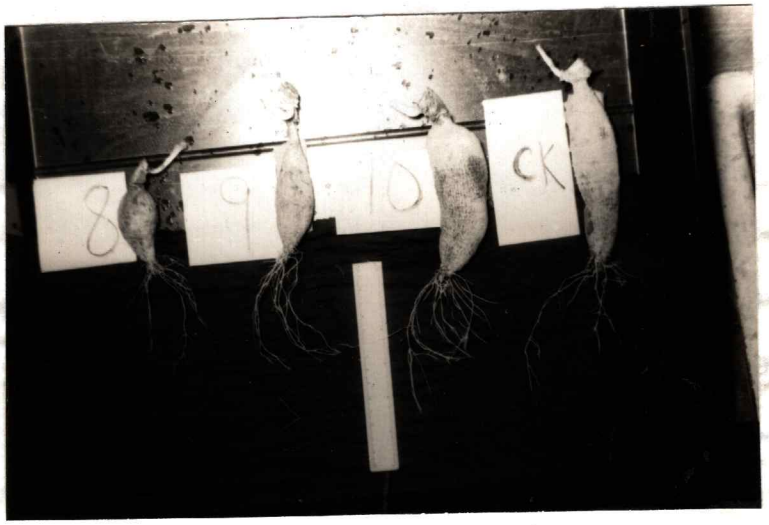

Fig. 21. Germination test of post-harvest MENA treatments. 8. 500 ppm MENA, 9. 1000 ppm MENA, 10. 3000 ppm MENA, Check. no MENA.

2. MH Treatments

Previous experiments by others have indicated that MH has poor qualities of penetration of dormant plant material and would no doubt give better sprout inhibition in storage if applied by injection or other similar mechanical means of getting the substance into the stock being treated. However it was decided to try MH on dahlia tubers with the same method as used for MENA.

In this experiment, using a spray method, MH did not give results indicating that it would be useful for inhibiting sprout growth, thus confirming previous work with other crops.

Figures 22 and 23 show no evidence of real effect on inhibiting sprout growth. There is a normal pattern in figure 24 with average number of sprouts. This is not significant since it is not the purpose to reduce the number of sprouts. All tubers and sprouting seems to be normal in figure 25.

Good normal growth was obtained with plants of 500 ppm and 1000 ppm MH as illustrated in figure 26. Treatments of 3000 ppm MH caused plants to be stunted or dwarfed as illustrated in figure 26. It is possible that tubers receiving 3000 ppm absorbed enough more of the chemical to make difference in plant growth.

The laboratory germination test as seen in figure 27, showed a reduction in root growth with 1000 ppm and 3000 ppm MH treatments.

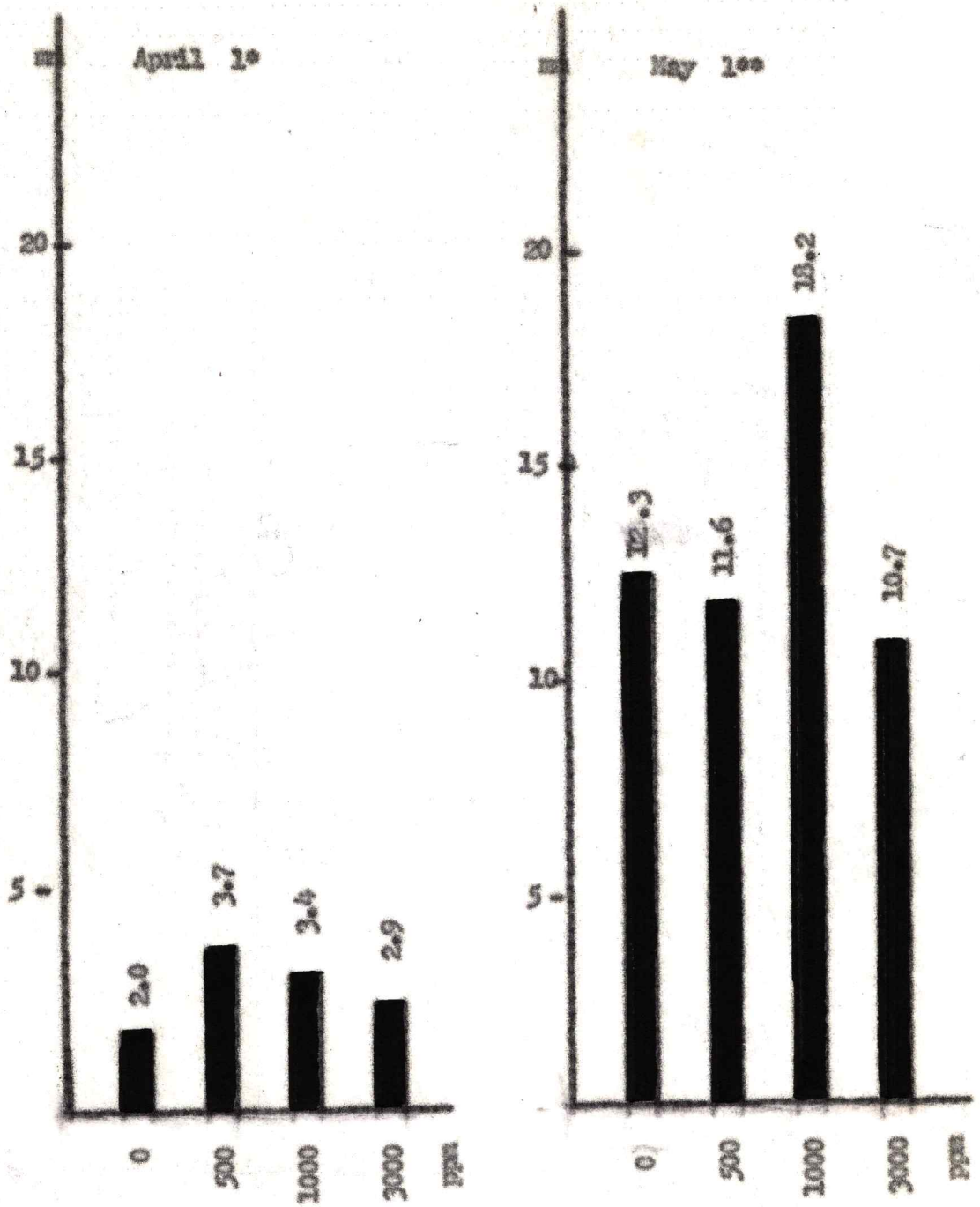

Fig. 22. Average sprout growth of dahlias with post-harvest (tuber) treatments using MH.

* Values represent measurements taken from 12 tuber clumps having one to two sprouts per clump.
** Values represent measurements taken from 12 tuber clumps having three to four sprouts per clump.

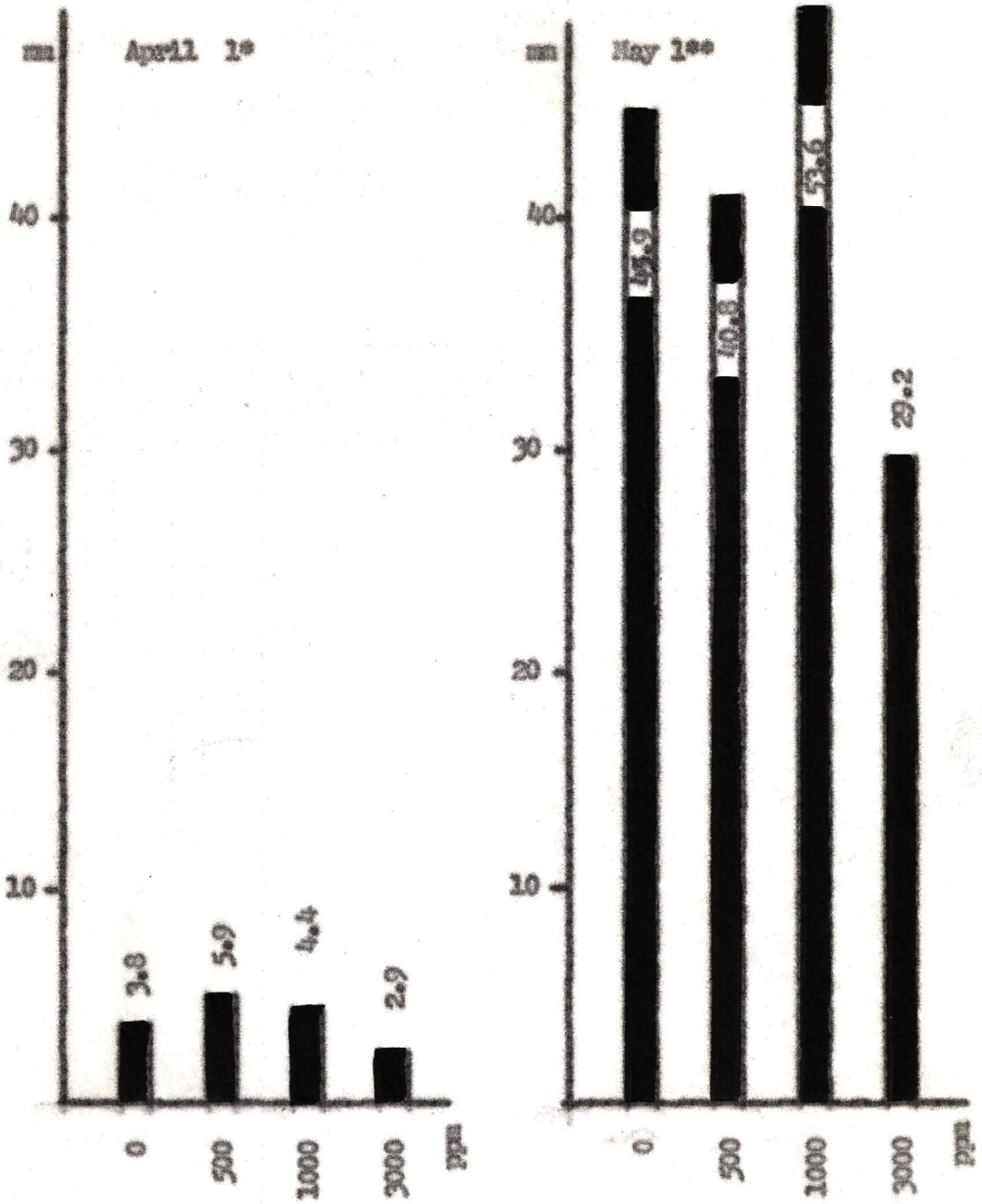

Fig. 23. Total sprout growth per clump with post-harvest (tuber) treatments using MH.

* Values represent measurements taken from 12 tuber clumps having one to two sprouts per clump.
** Values represent measurements taken from 12 tuber clumps having three to four sprouts per clump.

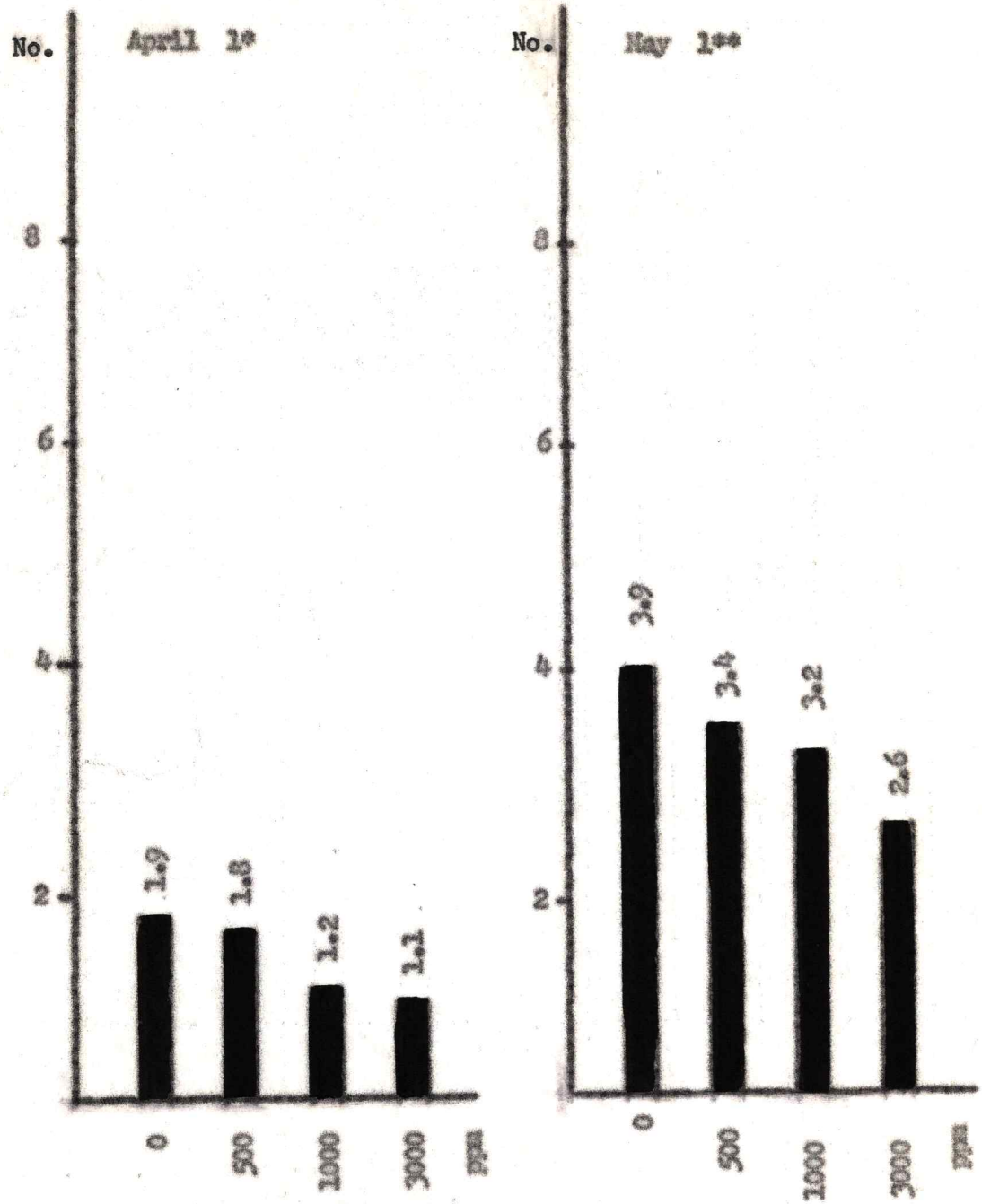

Fig. 24. Average number of sprouts per clump with post-harvest (tuber treatments using MH.

* Values represent measurements taken from 12 tuber clumps having one to two sprouts per clump.

** Values represent measurements taken from 12 tuber clumps having three to four sprouts per clump.

Fig. 25. Tubers of post-harvest MH treatments at the end of storage. 11. 500 ppm MH, 12. 1000 ppm MH, 12. 3000 ppm MH, Check. No MH.

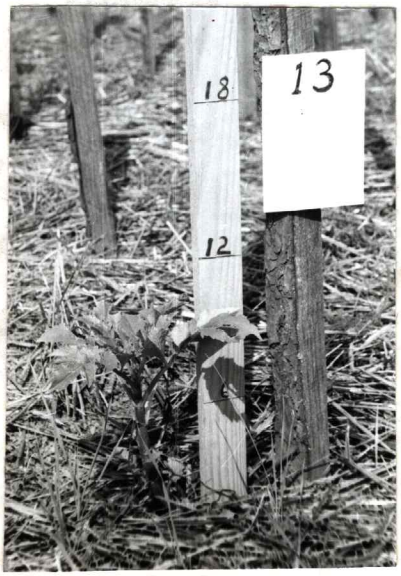

Fig. 26. Illustrations of plants in field test planting, after storage. 11. 500 ppm MH, 12. 1000 ppm MH, 13. 3000 ppm MH, Check. no MH.

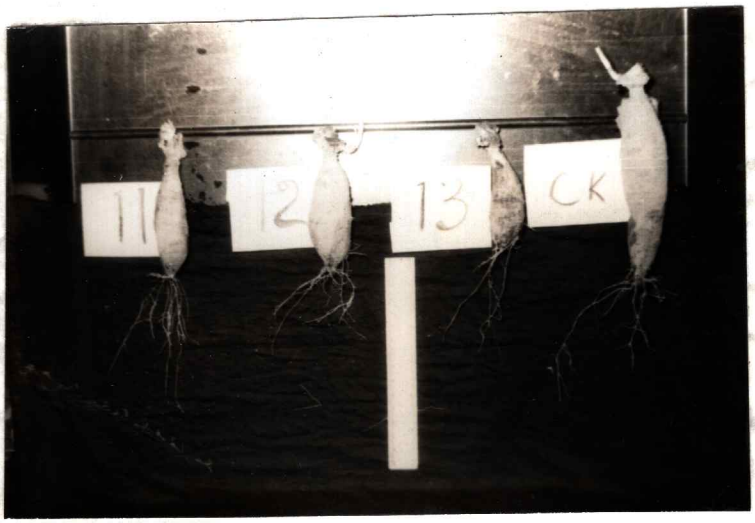

Fig. 27. Germination test of post-harvest MH treatments. 11. 500 ppm MH, 12. 1000 ppm MH, 13. 3000 ppm MH, Check. no MH.

CONCLUSIONS

Best sprout inhibition was exhibited with MENA treatments to the tubers. The two lower concentrations, 500 ppm and 1000 ppm, made good recovery from the effect of inhibition and exhibited good growth in the field test. Concentrations of 3000 ppm caused poor growth of tubers and was associated with a little more rotting than lower concentrations.

MENA applied as pre-harvest foliage sprays gave no appreciable reduction in sprouting.

Some sprout inhibition was exhibited with 3000 ppm MH post-harvest treatments, but subsequent growth was impaired. Lower concentrations of post-harvest treatments and none of the pre-harvest treatments of MH gave any appreciable control of sprouting.

Increased sprout growth was exhibited with 500 ppm MH pre-harvest and post-harvest treatments.

Best plant growth exhibited in the field test was with tubers which had received post-harvest treatments of 1000 ppm MH.

Root length was considerably increased by pre-harvest treatments of 3000 ppm MENA, and 1000 and 3000 ppm MH.

Chemical treatments, in general, caused some delay of the sprouts to emerge after planting. Some treated tubers were as much as three to four weeks later coming up than control tubers. Chemical treatments also caused a reduction in the number of sprouts. In most cases when there was a reduction in sprout growth there was also a reduction in the number of sprouts per clump.

MENA seems promising enough as a growth inhibitor or plant growth regulator, to warrant additional studies.

SUMMARY

1. An experiment was undertaken with dahlias using the commercial variety Robin Hood, to study the effects of methyl ester of naphthaleneacetic acid (MENA) and maleic hydrazide (MH) on sprouting in storage and growth after planting the tubers.

2. Treatments were made to plants approximately one month before frost and to tubers one month after harvest. Both MENA and MH were tested separately in the two instances and concentrations of 500, 1000 and 3000 parts per million were used.

3. The clumps of tubers were stored and observations of sprout growth was made.

4. Best sprout inhibition which also gave promise of good plant growth after storage was shown with treatments of 500 and 1000 parts per million MENA applied to the tubers after harvest. Treatments of 500 parts per million were slightly better than the higher concentrations.

5. In many cases adverse effects were associated with the highest concentrations of the two chemicals.

6. An acceleration of sprout growth was associated with the lower concentrations of MH and foliage treatments of MENA.

7. Chemical treatments caused delay in plants coming up, a reduction in the number of sprouts and more tubers to rot.

LITERATURE CITED

1. Acker, R.M. 1949. Growth of Three Varieties of Lilium Bulbs Stored in Vapor of Methyl Ester of Naphthaleneacetic Acid. Bot.Gaz.111:21-31.

2. Allen, R.C. 1937. Temperature and Humidity Requirements for the Storage of Dahlia Roots. Proc. Am. Soc.Hort.Sci. 35:770

3. Audus, L.J. 1953. Plant Growth Substances. Interscience Pub. Inc.,N.Y. 465 p.

4. Audus, L.J. and Ruth Thresh. 1956. The Effects of Synthetic Growth Regulator Treatments on the Level of free Endogenous Growth Substances in Plants. Ann. Bot. n.s. 20:439-459.

5. Avery, G.S.,Jr., Elizabeth B. Johnson, Ruth M. Addoms and Betty F. Thompson. 1947. Hormones and Horticulture. McGraw-Hill Book Co., Inc., N.Y. 326 p.

6. Beck, G.E., LeRoy Holm, and Ester Struckmeyer. 1957. Effect of Maleic Hydrazide on Vegetative Growth and Flower Production of Carnation. Proc. Am. Soc. Hort. Sci. 69:523-534.

7. Boysen Jensen, P. (Trans. by G.S. Avery, Jr. and P.R. Burkholder). 1936. Growth Hormones in Plants. McGraw-Hill, N.Y. 268 p.

8. Brody, H.D. and F.J. Francis. 1957. The Effect of Some Growth Inhibitors as Post-harvest treatments for Asparagus. Proc. Am.Soc. Hort. Sci. 70:281-285.

9. Callaghan, J.J. and R.W. VanNorman. 1956. Effect of Foliar Sprays of Maleic Hydrazide on Photosynthesis. Sci. 123:894.

10. Carolus, R.L., S.H. Lee and J.S. Vandemark. 1947. Effect of Methyl Ester of Naphthaleneacetic Acid on the Storage of Cauliflower. Bot. Gaz. 107:297-312.

11. Crandall, P.C. 1954. Relation of Pre-harvest sprays of Maleic Hydrazide to the Storage Life of Delicious Apples. Proc. Am. Soc. Hort. Sci. 65:71-74.

12. Currier, H.B., B.E. Day and A.S. Crafts. 1950. Some Effects of Maleic Hydrazide on Plants. Bot. Gaz. 112:272-280.

13. Denny, F.E. 1942. Use of Methyl Ester of Naphthaleneacetic Acid for Inhibiting Sprouting of Potato Tubers and an Estimate of the Amount of Chemical Retained by Tubers. Boyce Thom. Inst. Contrib. 12:387-403.

14. Denny, F.E., J.D. Guthrie and N.C. Thornton. 1942. Effect of the Vapor of the Methyl Ester of a-Naphthaleneacetic Acid on the Sprouting and Sugar Content of Potato Tubers. Boyce Thom. Inst. Contrib. 12:253.

15. Ellison, J.H. and Ora Smith. 1948. Effects of Spraying a Sprout Inhibitor on Potato Plants in the Field. Proc.Am.Soc.Hort.Sci.51:397-400.

16. Findlen, H. 1955. The effect of Several Chemicals on Sprouting of Stored Table-Stock Potatoes. Am. Pot. J. 32:159.

17. Greulach, V.A. and J.G. Haesloop. 1954. Some Effects of Maleic Hydrazide on Internodal Elongation, Cell Enlargement and Stem Anatomy. Am. J. Bot. 41:44-50.

18. Guthrie, J.D. 1939. Inhibition of Growth Buds of Potato Tubers with the Vapor of the Methyl Ester of Naphthaleneacetic Acid. Boyce Thom. Inst. Contrib. 10:325-328.

19. Guthrie, J.D. 1939. Control of Bud Growth and Inhibition of Roots at cut surfaces of Potato Tuber with Growth Regulator Substances. Boyce Thom. Inst. Contrib. 11:29-53.

20. Herman, Timm, J.C. Bishop and B.J. Hoyle. 1959. Investigations with Maleic Hydrazide on Potatoes as to Effect of Time of Application and Concentration, Upon Potato Performance. Am. Pot. J. 36:115-123.

21. Isbell, C.L. 1957. Response of Spring-Grown Potatoes to Treatment with Barsprout When held in Common Storage For Various Periods up to About Ten Months. Proc. Am. Soc. Hort. Sci. 69:427.

22. Isenberg, F.M., M.L. Odland, H.W. Popp and C.O. Jensen. 1951. The effect of Maleic Hydrazide on Certain Dehydrogenases in Tissue of Onion Plant. Sci. 13:58-60.

23. Isenberg, F.M. 1956. Use of Maleic Hydrazide on Onions. Proc. Am. Soc. Hort. Sci. 68:343-350.

24. Leopold, A.C. and W.H. Klein. 1951 Maleic Hydrazide as an Antiauxin in Plants. Sci. 114:9.

25. Marshall, E.R. and Ora Smith. 1951. Maleic Hydrazide as a Sprout Inhibitor for Potatoes. Bot. Gaz. 112:329-330.

26. Marth, P.C. 1943. Retardation of Shoot Development on Roses During Common Storage with Growth Regulating Substances. Proc. Am. Soc. Hort. Sci. 42:620-628.

27. Mastalerz, J.W. and F.J. Campbell. 1956. Maleic Hydrazide - A Substitute for Pinching potted Chrysanthemums. Proc. Am. Soc. Hort. Sci. 68:511-517.

28. Mitchell, J.W. and P.C. Marth. 1947. Growth Regulators. Univ. of Chicago Press, Chicago, Ill. 129 p.

29. Molero, F.J. 1956. The Effect of Maleic Hydrazide on Controlling Apical Dominance in Southern Peas. Proc. Am. Soc. Hort. Sci. 67:416-420.

30. Naylor, A.W. and E.A. Davis. 1950. Maleic Hydrazide as a Plant Growth Inhibitor. Bot. Gaz. 112:112-126.

31. Patterson, D.R. 1957. Effects of Pre-harvest Spray With Maleic Hydrazide on Sweet-Potatoes. Bot. Gaz. 118:265-267.

32. Powell, E.N. and R.C. Andreasen. 1957. Responses of Bench Grown Chrysanthemum morifolium to Maleic Hydrazide. Proc.Am.Soc.Hor.Sci. 70: 482-489.

33. Rao, S.H. and S.H. Wittwer. 1955. Further Investigations on the Use of Maleic Hydrazide as a Sprout Inhibitor for Potatoes. Am. Pot. J. 32:51-59.

34. Reynolds, E.S. 1939. Relation of Plants to Minute Doses of Inhibitive Substances. Plant Physiol. 14:385-387.

35. Salisbury, F.B. 1957. Growth Regulator and Flowering Survey Methods. Plant Physiol. 32:600-608.

36. Sawyer, R.L. and S.L. Dallyn.1956. Vaporized Chemical Inhibitors and Irridation, Two New Methods of Sprout Control for Tubers and Bulb Crops. Proc. Am. Soc. Hort. Sci. 67:514.

37. Sawyer, R.L. and S.L. Dallyn. 1957. Vaporized Chemical Control of Sprouting in Stored Potatoes. Farm Research. New York State Ag. Exp. Sta. 23(3):6.

38. Sawyer, R.L. and S.L. Dallyn 1958. Timing Maleic Hydrazide Sprays to Stage of Plant development. Am. Pot. J. 35:620-625.

39. Schoene, D.L. and O.L. Hoffmann. 1949. Maleic Hydrazide- A unique Growth Regulant. Sci. 109:558-590.

40. Smock, R.M., L.J. Edgerton and M.B. Hoffman. 1952. Inhibition of the Ripening Effect of Certain Auxins on Apples with Maleic Hydrazide. Proc. Am. Soc. Hort. Sci. 60:184-192.

41. Southwick, F.W. and W.H. Lachman. 1953. The Effect of Maleic Hydrazide and Water on the Rate of Respiration of Harvested Tomato Fruits. Proc. Am. Soc. Hort. Sci. 61:388-394.

42. Strudemeyer, B.E. 1953(abs). The Effects of Maleic Hydrazide on the Anatomical Structure of Croft Easter Lilies. Hort. Abs. 23:494.

43. Thimann, K.V. 1952. The Action of Hormones in Plants and Invertebrates. Academic Press Inc., N.Y. 228p.

44. Tukey, H.B. 1954. Plant Regulators in Agriculture. John Wiley and Sons, Inc., N.Y. 269p.

45. Wain, R.L. and F. Wightman(ed) 1955. The Chemistry and Mode of Action of Plant Growth Regulators. Proceedings of a Symposium held at Wye College (Univ. of London). Academic Press Inc., N.Y. and London, 312p.

46. Weller, L.E., C.D. Ball and H.D. Sell. 1957. Studies of Maleic Hydrazide Interaction with Thiol Compounds. Plant Physiol. 32:146-148.

47. Wittwer, S.H., R.C. Sharma, L.E. Weller and H.M. Sell. 1950. Pre-harvest Foliage Sprays of Certain Growth Regulators on Sprout Inhibition and Storage Quality of Carrots and Onions. Plant Physiol. 25:539-549.

48. Wittwer, S.H. and D.R. Patterson. 1951. Inhibition of Sprouting and Storage Losses in Onion, Potatoes, Sugar Beets and Veg. Root Crops by Spraying the Plants in the field with Maleic Hydrazide. Mich. Ag. Exp. Sta. Quar. Bul. 34:3-8.

49. Zimmerman, P.W. and A.E. Hitchcock. 1937. Dahlia Root Storage At Different Temperatures. Boyce Thom. Inst. Professional Paper. 1(21):210-211.